New Hampshire Department of Environmental Services

GENERIC QUALITY ASSURANCE PROJECT PLAN FOR FLUVIAL MORPHOLOGY DATA COLLECTION

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Generic Quality Assurance Project Plan for Fluvial Morphology Data Collection

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Prepared by
Sean Sweeney / Susan Simpson
Provan & Lorber, Inc.
34 School Street
Littleton, NH 03561

Updated by
Shane Csiki
NH Dept. of Environmental Services
29 Hazen Drive
Concord, NH 03301

319 Program Manager: ______________________

Signature / Date
Eric Williams, NHDES

Fluvial Erosion Hazard Program Manager ______________________

Signature / Date
Shane Csiki, NHDES

Program Quality Assurance Coordinator: ______________________

Signature / Date
Jillian McCarthy, NHDES

NHDES Quality Assurance Manager: ______________________

Signature / Date
Vincent Perelli, NHDES

USEPA Project Manager: ______________________

Signature / Date
Erik Beck, US EPA Region I

USEPA QA Manager: ______________________

Signature / Date
Stephen DiMattei, US EPA Region I

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Cover Photos:
Top left - Palmer Brook, Littleton, NH (E4 - stream type above, conversion to C4 stream type at cross-section location
Center - Caleb Brook approaching the bankfull stage, Lancaster, NH (E4 - stream type)
Bottom - Bog Brook, Stratford Hollow, NH (C3 stream type)

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A3 – Distribution List

This is a generic QA Project Plan (QAPP) for activities related to fluvial geomorphology data collection. A Site-Specific Project Plan (SSPP) will be written for project-specific work. This generic QAPP serves two primary audiences; 1) grant projects funded through NHDES using EPA Clean Water Act Section 319 money that involve fluvial geomorphology data collection, and 2) New Hampshire Geological Survey Fluvial Erosion Hazard Program projects. Table 1 lists people who will receive copies of the approved QAPP and any subsequent revisions.

Table 1. QAPP/ SSPP Distribution List

QAPP Recipient Name	Project Role	Organization	Telephone number and Email address
Jillian McCarthy	Program QA Coordinator	NHDES Watershed Management Bureau	603-271-8475 jillian.mccarthy@des.nh.gov
Shane Csiki	Fluvial Geomorphology Specialist	NHDES New Hampshire Geological Survey	603-271-2876 Shane.Csiki@des.nh.gov
Vincent Perelli	NHDES Quality Assurance Manager	NHDES Planning, Prevention & Assistance Unit	603-271-8989 vincent.perelli@des.nh.gov
Erik Beck	USEPA Project Manager	USEPA New England	(617) 918-1606 beck.eric@ epa.gov
Stephen DeMattei	USEPA Quality Assurance Officer	USEPA New England	(617) 918-8369 dimattei.steve@epa.gov

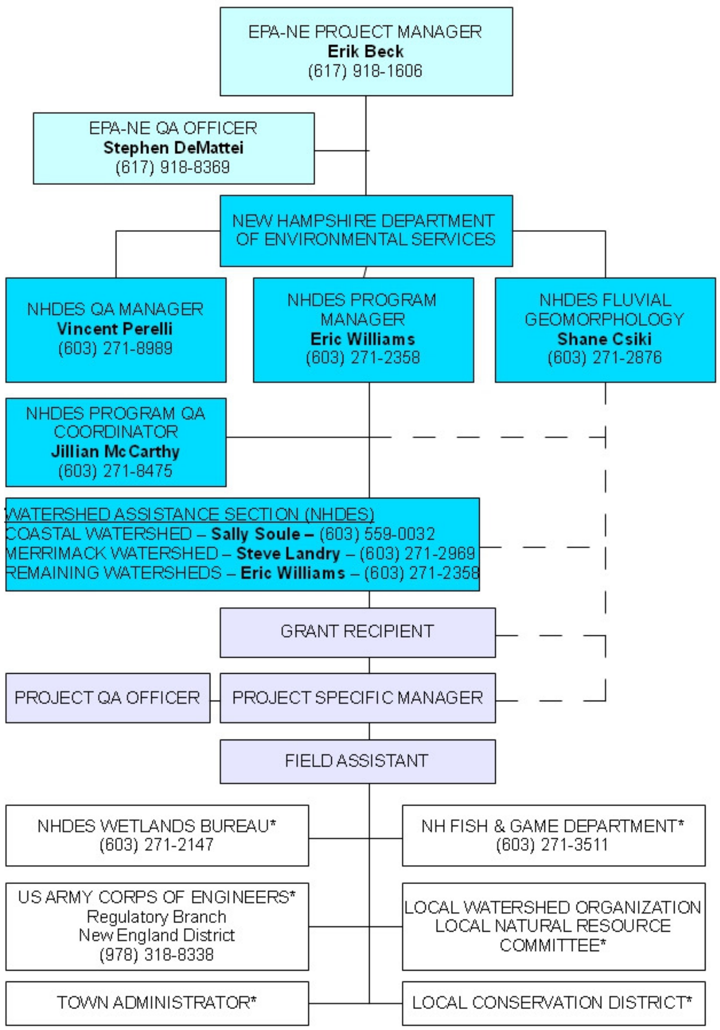
In addition, several people involved in site-specific work will receive the generic QAPP and SSPP as needed. Those people include:

- Project Manager
- Field Team Leader
- Data Processor
- QA Officer
- Data Reviewers
- Essential Contractor or subcontractor personnel (hydrologist, geomorphologist , or engineer)
- Volunteers (if utilized) and other project participants not listed above

A4 – Project/Task Organization

The following project organizational chart lists the roles and lines of communication among those individuals or organizations involved in stream morphology projects. Contact information and names of job-specific grant recipients, individuals, and organizations will be included in the SSPPs. Some organizations as determined by the needs of the project are optional and can be omitted (see non-color shaded boxes in Figure 1).

Figure 1. Project organizational chart



* - Partners specific to each project and documented in the site specific project plan.

Table 2 identifies the roles and responsibilities of those individuals involved in the project. Project specific roles will be identified in the SSPP. Fluvial geomorphology data collection will be performed by staff members with expertise in fluvial geomorphologic science, with either demonstrated training in fluvial geomorphology, or by a licensed professional engineer or professional geologist, and have experience conducting fluvial geomorphology evaluations using established protocols (e.g., the Vermont Agency of Natural Resources' Stream Geomorphology Assessment Protocols, or the New Hampshire implementation thereof). The project manager will be responsible for submitting an approved SSPP.

Table 2. Personnel Responsibilities and Qualifications

Name and Affiliation	Responsibilities	Qualifications
Qualified Hydrologist, Engineer, Geomorphologist, or similar	Project manager	Trained in stream morphology data collection, analysis, interpretation, and stream survey techniques
Field Assistant	Assist with field data collection	Trained in stream survey methods
Qualified Engineer or technician	QA/QC officer	Trained in stream morphology data analysis and interpretation
Jillian McCarthy NHDES Watershed Management Bureau	Reviews QAPP preparation and other QA/QC activities	On file at NHDES
Vincent Perelli NHDES Planning, Prevention & Assistance Unit	Reviews and approves QAPPs and Site-Specific Project Plans (SSPPs)	On file at NHDES
Steve Landry NHDES Watershed Management Bureau	Reviews and oversees projects funded by DES 319 Restoration grants in Merrimack watershed	On file at NHDES
Sally Soule NHDES Watershed Management Bureau	Reviews and oversees projects funded by DES 319 Restoration grants in coastal watershed	On file at NHDES
Eric Williams NHDES Watershed Management Bureau	Reviews and oversees projects funded by DES 319 Restoration grants in Connecticut, Saco, and Androscoggin watershed	On file at NHDES
Shane Csiki NHDES New Hampshire Geological Survey	Technical oversight responsibilities for stream morphology data collection and quality control for projects funded and managed by DES.	On file at NHDES

Principal data users may include the project manager, local landowners and government agencies, NHDES, and the US EPA. Secondary data users may include the NH Fish and Game Department, NH Department of Safety – Division of Homeland Security and Emergency Management, NH Office of Energy and Planning, and the US Army Corps of Engineers. Other secondary data users may include the Regional Planning Commissions, local Conservation District, local watershed associations and advisory committees, and the public. Coordination with state, federal, or local organizations, or the public, for the purposes of initial data collection, eyewitness accounts, etc. may occur.

A5 – Problem Definition/Background

Preserving, improving, and restoring the physical and biological integrity of our nation's waters are goals of the Clean Water Act expressed through the implementation of programs by the New Hampshire Department of Environmental Services. In addition, protection of public health and safety relative to flooding is an additional important goal of NHDES. To that end, fluvial geomorphology data are used as a decision-making tool in determining what actions are needed to meet those goals.

To fulfill these goals, NHDES uses three phases of assessment for the characterization of stream morphological condition. A Phase 1 assessment provides an overview of the general physical characteristics of a river and its valley through examination of existing datasets such as digital topography (including LiDAR where available), current and historical aerial imagery, geologic information, local and regional knowledge, and a river or watershed windshield survey to verify information gained from the aerial photography and to gain a better understanding of form and processes operating throughout the watershed. Phase 1 information may be used to target locations for more detailed Phase 2 assessments, and/or to provide the necessary background on river and watershed character to inform both the Phase 2, and Phase 3 assessments.

Phase 2 assessments are field-based surveys which gather scientifically-sound information about the river channel and directly adjacent floodplain to evaluate and identify fluvial erosion hazards, and stream restoration opportunities for improvement of water quality and public health and safety. These assessments gather a variety of information along miles of rivers and streams to characterize river condition and health. A variety of river features may be spatially mapped to assist in identifying these conditions, hazards and opportunities.

Phase 3 assessments are more detailed, site-specific evaluations that gather scientifically-sound information about the specific processes occurring at a site in aid of the design of stream restoration or stabilization mitigation projects, or to investigate particular high-risk water quality or public safety concerns. NHDES employs two variants of Phase 3 assessments – one of which is the commonly used reference reach assessment approach (Phase 3R); and the second which employs a more site-specific data collection suite (Phase 3S). Phase 3S provides for the collection and use of high-density data sets in an analytical approach.

A Phase 3 assessment may be used either after a Phase 2 assessment, or if project goals are already known, as a stand alone assessment. Phase 3 assessments incorporate a greater degree of morphological and engineering parameters than either the Phase 1 or Phase 2 assessments.

This generic QAPP covers the work of either NHDES staff, or a professional who will be hired, either by NHDES or a grant recipient, to conduct the Phase 1, 2 and 3 assessments, either individually or in combination, to identify existing problems, and determine appropriate solutions to these problems. Data may also be used in research projects, such as the development of regional hydraulic geometry curves, or to provide outreach. Additional potential uses for these data are:

- Monitoring trends in physical channel characteristics over time;
- Quantifying environmental impact from adjacent land uses, in-stream structures, or similar activities;
- Assessing stream and watershed response to management activities;
- Providing stream channel data for water allocation decisions;
- Providing stream channel data for identification of stream restoration and hazard mitigation opportunities;
- Supporting resource inventories (habitat, water quality, vegetation);
- Allowing comparisons between different streams or distinct reaches of the same stream;
- Contributing to regional, national, and international databases;
- Stream restoration, design and, monitoring;
- Predicting potential channel response to in-stream structures, land-use changes, flow regime changes, or similar;
- Design of in-stream structures;
- Support for delineation of areas at risk to flooding, fluvial erosion hazards, and riparian impacts;
- Regulatory permitting decisions,
- Bridge and culvert design, and
- Identification of stream crossings that are impediments to passage of flow, sediment, and aquatic organisms for prioritization of replacements.

Geomorphic stream measurements provide an objective way of assessing stream characteristics and conditions. They reveal problems by providing the data needed for classification, assessment, and restoration. When the source of problems impacting water quality or public health and safety is not fully understood, work performed with the best intentions to repair a problem can instead cause greater river adjustments, and actually create a bigger problem.

Stream morphology data are frequently used to determine appropriate methods of restoring channel form and aquatic habitat. In some cases, however, the cause of stream instability is not readily apparent. Stream morphology data often can provide insights into underlying causes and at the same time provide the information necessary to develop a solution.

Streams and adjacent lands provide habitat for aquatic organisms and riparian vegetation. When this habitat is disturbed, the populations which depend upon it are also affected. Channel form is influenced by interrelated variables including slope, width, depth, velocity, discharge, boundary roughness, sediment size, and sediment load. A change in any variable, whether naturally occurring or altered by humans, leads to adjustments in other variables and stream morphology as a whole.

One example of human-induced change is channel straightening which results in a steeper channel slope. The steeper slope increases velocity and channel shear stress which increases the rate of sediment transport. This typically leads to channel bed downcutting (increased depth) and a lowering of the local water table. This can result in a shift from hydrophytic riparian vegetation to more mesic species. Bank erosion and lateral channel migration often ensue (channel widening, increased sediment load, and decreased boundary roughness), as the straightened river attempts to recreate meandering. These chain-reaction of adjustments can result in degradation of aquatic and riparian habitats and water quality, in addition to impacting public health and safety. In this scenario bank erosion would likely be the most obvious sign of instability. Hard bank armoring is often prescribed, but this treats only a symptom of the problem, not the cause, and does little to improve aquatic and riparian habitats. Stream morphology data collected in such a stream reach would identify the root of the problem (slope) and these same data collection techniques could be employed on a stable "reference" stream reach to determine the proper slope, width, depth, etc, or in aiding an engineered solution to the problem, or both. Restoring the appropriate morphology will lead toward the restoration of watershed water quality.

A6 – Project/Task Description

Project tasks with their associated deliverables are presented in the table below. Dates are omitted from this generic QAPP chart and will be included in the SSPPs. Tasks 1 and 2 are applicable to all three phases of stream morphology collection, while Tasks 3 through 6 are required only for a Phase 3 assessment.

Table 3. Project Schedule Timeline

Activity	Dates (MM/DD/YYYY)		Product / Type of Measurement	Due Date
	Anticipated Date(s) of Initiation	Anticipated Date(s) of Completion		
Task 1-Site-Specific Project Plan (SSPP) Preparation		*(Before beginning Task 2)*	SSPP Document	
Task 2 – Collection and processing of data (When SSPP is approved)	*(competion of Task 1))*		Aerial photos, Stream Gage Data (primarily for Phase 3), FEMA, Flood Insurance Studies (FIS), Phase 1 reach breaks, Phase 2 geomorphic assessment	
Task 3 – Stream Gage Survey (if gage is available)	*(Follows completion of Task 2)*		Estimate bankfull discharge and stage at project reach	
Task 4 – Reference Reach Survey	*(Can be done*		Channel Profile	

	before Task 3)			
Task 5 – Project Reach Survey	*(Can be done before Task 3)*		Field survey, channel classification	
Task 6 – Sediment Transport Evaluation	*(Final Field Task)*		Channel materials and river transport power	

The process of taking channel measurements is systematic. Using consistent techniques will provide sound and factual information which will be easily replicated over a period of years and through changes in personnel.

<u>Task 1 – Preparation of Site Specific Plan (all phases of assessments)</u>

Site Specific Project Plans (SSPPs) will be prepared by the Project Manager, reviewed and approved by the Project QA Manager and the NHDES QA Manager prior to field work, and a copy retained in the company project files. A copy of the approved plan will be sent to the DES Program QA Coordinator and to the DES Fluvial Geomorphology Specialist. The Project Manager is responsible for communicating the SSPP and other QA/QC requirements to other field sampling staff that may be working on the project.

The SSPPs will reference this generic QAPP, including the full document name, US EPA Request for Assistance (RFA) ID #, and the US EPA approval date. Deviations from (and stipulations not addressed in the generic QAPP) will be incorporated into the SSPPs. Details included in the SSPPs will be site information, rationale, project description and schedule, analysis, and reporting. Additional information will be considered and added when applicable. Also, the Project Manager will be responsible to locate or produce procedures for any deviations and stipulations, in particular, sampling and testing required for a project that is not described in the generic QAPP, in which case the DES Program QA Coordinator and DES Fluvial Geomorphology Specialist will review and approve. An example outline of the SSPP follows.

Site Information

Site map
Sample location map
Personnel identification and organization

Rationale

Problem Definition
Historic Data
Matrix of Concern

Project Description and Schedule

Study Design (sampling location, Sampling and Analysis Method/SOP requirements, reference to the Data Collection Protocols used and any deviations from the protocols)
Procedures and Requirements

Data Analysis
Special Personnel Training (as needed)
Instrument/Equipment Maintenance, Tests, and Inspection (as needed)
Instrument/Equipment Calibration (as needed)

Reporting
To whom results and discussion are reported

<u>Task 2 – Collection and processing of data</u>
<u>Phase 1 assessments</u>
Implementation of the Phase 1 geomorphic assessments has its basis in the Vermont Stream Geomorphic Assessment Protocols, Phase 1, as implemented in New Hampshire. Phase 1 assessments are required inputs to a Phase 2 assessment. Copies of these protocols may be obtained by contacting the fluvial geomorphology program coordinator at NHDES. Data collection and processing is undertaken as follows:

1. Obtain historical and recent aerial photography, and where available, LiDAR.
2. Obtain available geologic information including soils and land cover data.
3. Obtain information on river assessments that may have already been completed in the area.
4. Obtain historical information from town officials, local watershed organizations, and where applicable, citizens.
5. Identify and delinate river or stream reaches on which to conduct Phase 2 assessments.
6. Delineate stream centerlines to the 1:5000 scale, using the most current version of orthophotography available.
7. Delineate meander centerlines from the 1:5000-scale derived stream centerlines.
8. Define valley walls, using digital orthoquads or LiDAR, where available. DES Fluvial Geomorphology staff can provide technical assistance with this item.

<u>Phase 2 assessments</u>
Implementation of the Phase 2 geomorphic assessments has its basis in the Vermont Stream Geomorphic Assessment Protocols, Phase 2, as implemented in New Hampshire. These are field-based assessments, with the essential data collection and processing elements should follow the Vermont Stream Geomorphic Assessment Protocols, 2007 version, with the following exceptions:

1. Step 2 (stream channel data) of the protocol follows the 2009 version of the Vermont Stream Geomorphic Assessment Protocols.
2. The use of hand-drawn sketches is optional, and is at the discretion of field data collection staff.
3. Field data collection staff will collect a digital photographic log of the river or stream, with GPS points of photographs collected. Photographs will be collected at each cross-section, and include an upstream view, downstream view, right bank view, and left bank view, while ensuring that the cross-section with measuring tape

stretched across the river or stream is visibly incorporated into at least two photographs. Where possible, the compass directionality of photographic views should be documented.

4. If a river reach or segment is not wadeable, and is not located within an impoundment, cross-section data collection can be performed by boat or canoe, which will be tied to a tagline that is fixed across the river or stream at a cross-section. Bankfull depth readings can then be collected along the cross-section from the boat or canoe affixed to the established tagline.
5. On cross-sections, bankfull depth will be measured at additional locations on an established cross-section where morphological change occurs. These locations include situations where the bed material character visibly changes from one size class to another; where bed elevation abruptly changes; and the start, middle and end of bars.
6. In situations where reaches are not wadeable even at low flow, a bed sampler can be operated from a boat or canoe, and dominant bed material size may be estimated by visual inspection. This option is not applicable in situations in which the river or stream is wadeable.

Phase 3 assessments
Phase 3 geomorphic assessments in New Hampshire do not explicitly follow the Vermont Stream Geomorphic Assessment Protocols, Phase 3, as compared to the Phase 1 and Phase 2 assessments. The core structure of the New Hampshire version of Phase 3 assessments is outlined below and in the tasks that follow. First, the following data and information will be collected to the extent available, and reviewed to maximize the understanding of the project area.

1. Obtain historical and recent aerial photography, and where available, LiDAR, or more precise contour interval data.
2. Obtain available geologic information.
3. Obtain historical information from town officials, local watershed organizations, and where applicable, citizens.
4. Locate project reach on a current USGS map and determine drainage area.
5. Estimate bankfull discharge, width, mean depth, and cross-sectional area from regional hydraulic geometry curves.. Discharges for multiple flow values may be estimated through use of USGS StreamStats for New Hampshire.
6. The local USGS office in Pembroke has completed water resources investigation reports for sites throughout New Hampshire. They should be contacted to determine if they have investigations or hydrologic analyses that have been completed for the project area of interest that could improve understanding of the processes operating in the project area. Most of these reports are also available through their website.
7. The items outlined in Steps 1 through 6 will be performed for both a reference reach and project reach (Phase 3R assessment) or only the project reach (Phase 3S assessment).
8. Obtain active and inactive stream gage records including instantaneous annual peak discharge for the period of record (minimum 20 years). If the site of interest is located on a river that is gaged, discharge values will need to be scaled for the difference in watershed sizes between the site of interest and the gaged site. For an ungaged site,

either statistical procedures may be employed to estimate discharge compared to another nearby gaged watershed, or StreamStats for New Hampshire may be used. Stream flow measurement data (USGS 9-207 forms) may be used to estimate and verify the bankfull discharge and channel cross-sectional geometry at the gage sites and project reach.

9. Obtain Federal Emergency Management Agency (FEMA) Flood Insurance Studies (FIS), including hydraulic model input data, if available. These input data will include channel bed elevations at several locations (cross sections) within the flood insurance study reach. These elevations may be compared to present day channel elevations to determine if the channel has lowered (degraded) or risen (aggraded).
10. Contact NHDES to determine if additional fluvial geomorphology data is available for the reach or segment of interest, or in nearby watersheds. As more rivers and streams are assessed in the state using the Phase 1 and 2 assessment protocols, data may be available to provide additional insights on the condition of a reach that should be considered during project survey and design to maximize success. Additionally, stream restoration projects can incorporate reference reach surveys. With increasing amounts of stream geomorphology data from around the state, NHDES can provide technical assistance in identifying river reaches that are in geomorphologically reference or good condition (determined from Phase 2 protocols) that could be used for reference reach surveys (Task 4 below).
11. Obtain any information, including existing design plans, for infrastructure, including culverts, berms, bridges and roads that exist within the project reach.
12. Phase 3 assessment work will require permission from abutting landowners. Data on property ownership so that contact can be established will need to be obtained.

<u>Task 3 - Bankfull Calibration at Stream Gage (Phase 3 assessments)</u>

One of the most important components of any stream morphology project is accurately determining the stage associated with bankfull, or channel forming discharge. The most accurate and objective method of determining bankfull stage is via calibration at a stream gage with a long period of record (20 years minimum data). Stream survey procedures are described in Appendix A. Procedures for calibrating bankfull discharge at a USGS gaging station are contained in Appendix B.

If there is no gage located upstream, downstream, or within a project reach, as is often the case, bankfull calibration at a long-term gage on a channel of the same stream-type, of similar drainage area (+/- 50 %), and a similar hydrophysiographic region should be performed. When using a gage from a different watershed, the watershed that is used should be one that is adjacent to that being assessed to maximize the accuracy of the bankfull calibration. Cross-sectional geometry and discharge characteristics at the bankfull stage can then be adjusted for the project reach drainage area (*i.e.*, Bankfull discharge vs. drainage area, bankfull width vs. drainage area, bankfull cross-sectional area vs. drainage area, mean bankfull depth vs. drainage area). These relationships will serve as a guide for determining the bankfull stage at the project site.

If no suitable gage can be found, regional hydraulic geometry curves for NH (available from the New Hampshire Geological Survey at NHDES) should be used in conjunction with best professional judgement in determining the bankfull stage. USGS StreamStats for New Hampshire may also be used, in conjunction with the New Hampshire hydraulic geometry curves in determining the bankfull stage.

Task 4 – Reference Reach Survey (Phase 3R assessments)

A stable section of channel, upstream, or in an adjacent watershed which has similar valley characteristics, and upstream watershed area as the proposed project site, should be surveyed. This "reference reach" can be used as one component in determining the appropriate channel dimension, pattern, and profile of the project reach.

It is critical to select a reference reach from a nearby watershed or upstream reach in which disturbance of the upstream watershed has been minimized. NHDES can provide technical assistance in selection of potential reference reaches with the Phase 2 assessment data increasingly available. For areas in which Phase 2 data is not yet available, a reach selected for reference should be one that is free to adjust its channel boundaries; has consistent bankfull indicators; and for which these conditions exist consistently for approximately 20 bankfull widths; and lastly, where the upstream watershed is not known to have been extensively disturbed or modified. For projects that pose difficulties with the reference reach approach (such as where a river has undergone a major channel path change, or if the stream flows through a completely urbanized watershed), it is possible that the Phase 3S approach may be considered.

Cross-sectional features (width, cross-sectional area, mean depth, max depth etc.) will be measured in as many different channel features (riffles, runs, pools, and glides) that exist in the reference reach. Profile characteristics including average water surface slope, riffle slope, pool-to-pool spacing, and pool length will be surveyed along with channel pattern features such as meander length, meander radius and belt width. Differences in drainage area between the project and reference reaches must be accounted for by developing dimensionless ratios. Pebble counts will also be conducted to characterize the particle size dominant in the reach.

Additional information about Reference Reach surveys can be found in Appendix C and Plan View measurements can be found in Appendix E as well as Section B2.

Task 5 – Project Reach Survey (Phase 3 assessments)

Perform field survey of project reach.

Phase 3R assessments

This will include several monumented cross-sections, a longitudinal profile of the entire reach, plan view measurements, and a pebble count for stream classification purposes (See Appendix D). GPS points of cross-section locations should be collected, for ease of locating in GIS or CAD, from which maps may be produced. If possible, a reference elevation marker shown on a FEMA Flood Insurance Rate Map, national geodetic survey marker, or an elevation mark on transportation infrastructure such as a road or bridge should be used as a survey benchmark.

These following data will be collected:
1. Cross-section surveys (minimum one for every 5 bankfull widths)
   - Natural ground, channel bed, and water surface elevations along each cross-section. Surveys should extend outward across the floodplain a sufficient distance to allow accurate modeling of flows in a HEC-RAS model.
2. Profile survey
   - Thalweg, water surface, bankfull, and top of bank along the profile (minimum 20 bankfull widths or 2 meander wavelengths in length). Also note the cross-section locations along the profile.
3. Pebble count
   - Perform Wolman Pebble Count (Appendix D).
4. Plan View measurements
   - Stream length
   - Valley length
   - Meander length (L_M)
   - Meander radius (R_C)
   - Belt Width (W_{BELT})
   - Arc Length (L_{ARC})

   See Section B2 for detailed discussions on each type of data collection.

Phase 3S assessments
The data collected in the project reach in a Phase 3S assessment is designed to provide the detail required for analytical flow and sediment transport modeling when required. While much of the data collected is commensurate with that in a Phase 3R, additional detail is necessary to fulfill requirements of flow and/or sediment transport models. These adjustments to the Phase 3R procedure include:

- The total number of cross-sections surveyed will be dependent on the length of the reach in which data is being collected, but should be spaced at distances no greater than 1.5 channel widths apart.
- Perform a topographic survey of the reach with a total station that uses either a local or GPS-based coordinate system, capable of survey accuracy to 0.02 feet. In this method, the survey is not conducted on cross-sections or in a longitudinal profile. Instead, it is a detailed survey of points in an area that captures as many different landscape features as possible in order to bring all of the points, their locations and associated elevation values into GIS or CAD for creation of a topographic map. Point densities will vary spatially with higher point densities in topographically complex areas, and lower densities in more topographically level areas. This method is required if two-dimensional flow modeling is chosen to be employed at a site. It is important that the total station is referenced to a well-known and defined datum for accuracy.

- In situations where Phase 3S is required for applications that are perennially not wadeable (*i.e.*, upstream of a dam), a topographic survey within the river channel can be conducted from within a boat, using a fathometer, capable of 0.02 foot accuracy, paired with a GPS system. Channel bed elevations are determined by subtracting water depths from elevations of the water surface, which is tied to surveyed benchmarks of known elevation. Particle size can be determined through collection of bed samples using a grab sampler for sieving analysis.
- With a detailed topographic survey, a specific longitudinal profile survey is not required, as this can be derived from the topographic survey data.

<u>Task 6 – Sediment Transport Evaluation (Phase 3 assessments)</u>
Perform riffle pebble count and particle size distribution analysis of sub-pavement or bar sample. These data will be used to determine the size of material available as bedload and the combination of depth and slope required to effectively transport this material

These following data will be collected:

- Riffle pebble count
- Bar/bulk sample

A7 – Quality Objectives and Criteria

The quality of field data is extremely important as subsequent decisions may be based upon it. In this generic QAPP all streams assessed in Phase 3R must be wadeable for measurement purposes, in other words, shallow enough to walk about the water in a safe manner. Streams assessed using Phase 2 and Phase 3S do not necessarily have to be wadeable, though such assessments are largely conducted on wadeable streams.

Data quality assessment criteria and objectives for measuring data are described below.

<u>Precision</u>: USGS Stream Gage Data, USGS StreamStats, FEMA Flood Insurance Studies, are all published government documents, so they have inherent acceptable accuracy and precision standards. Aerial photos and LiDAR acquisitions should be flown by a reputable agency. Multiple state and federal partners collaborate in aerial imagery acquisition, and photos can be found already orthorectified with known scale. Otherwise scale can be calculated using an average of 5 measurements between easily identifiable points, minus any outliers.

For Phase 1 assessment data preparation, one individual should delineate stream and meander centerlines, reach breaks and valley walls. During Phase 2 and Phase 3 stream data collection, precision can be ensured by using the same analytical instruments throughout the whole data collection process. Benchmarks will be fully referenced. Checking for errors and inconsistencies will be performed regularly in the field by each field team member, and acceptable note-taking and paper and electronic reporting formats will be adhered to. For quality control purposes, when possible, duplicate measurements can be taken by the field assistant. Precision can also be improved by insuring the instruments are properly calibrated according to manufacturer's specifications, and are handled with care throughout the whole process. One should ensure scales are zeroed and instruments have remained level before each measurement.

The project manager is ultimately responsible for quality control on all collected data to enable discovery and correction of errors and inconsistencies.

Accuracy/Bias: Table 4 displays applicable limits, with the understanding that when field measurements are taken, any measurements taken to a higher precision will make river surveys easier to close as well as produce more accurate data.

Table 4. Minimum Standards for Measurement Tolerances

Medium	Analytical Method	Measured to	Acceptable Limits Accuracy to +/-
Aerial Photo	Scale Measurements	0.05 inches	50 Ft
Scaled USGS Topo Map	Determining comparable distances	0.05 inches	$^{1}/_{30}$ inches (@ 1:24,000 scale)
Survey tape	Distance measurement – non-stretchable durable waterproof tape, preferably fiberglass or steel, graduated in 0.1 feet	0.01 Ft	0.01 Ft
Survey Rod	Elevation measurement	0.01 Ft	0.01 Ft
Scale	Weight measurement	1 oz	1 oz
Field Survey	Vertical Survey closure	0.01 Ft	$.007\sqrt{(^{\text{Total Dist}}/_{100})}$
Survey Level	Benchmark measurement	0.01 Ft	0.01 Ft
Survey Level	Elevation – channel bed and adjacent land	0.01 Ft	0.01 Ft
Survey Level	Elevation – water surface	0.01 Ft	0.01 Ft
Survey Level	Cross-section elevation Measurement locations	Max. Spacing = $^{\text{Bankfull Channel Width}}/_{20}$	N/A
Survey rod	Plumb	Bubble	Second ring
GPS	Coordinate Referencing	Lat/Long	5 Ft*
Total station/GPS Topographic survey	Horizontal location and vertical elevation	0.02 Ft	0.02 Ft

- For Phase 2 assessments, subject to accuracy degradation caused by foliated trees that adjoin many smaller order streams in New Hampshire.

The quality and accuracy of field survey data shall be ensured in the following ways, as appropriate for Phase 2 and Phase 3 assessments:

- Calibrate level or electronic or GPS-RTK total station.
- Survey closure in the field – A geometric or mathematically closed survey provides checks on the measured elevations and distances. In a closed polygon differential leveling traverse (mathematically and geometrically closed) the survey path returns to the starting point of known elevation or benchmark (BM). A linked traverse (mathematically closed, geometrically open) should end at a point that has a positional accuracy equal to or greater than that of the beginning benchmark. The difference between the known elevation of the benchmark and the calculated elevation is the error. A closure of 0.02 feet is generally acceptable for river surveys. Open traverses should be avoided, because they offer no means of checking for errors and mistakes.

- Survey tape will be stretched tightly to avoid sagging (if channel is so wide that sagging cannot be avoided, then a tag line will be used), and situated so that it is aligned perpendicular to the main thread of flow. One field team member should stand on the streambank and check the alignment of the tape relative to the main flow path, and adjust if necessary.
- For Phase 3 assessments, data will be plotted in the field to check for errors.

Any atmospheric or stream conditions that might influence the measurements should be accounted for. For example, cold temperatures can shorten the length of a metal tape measure, resulting in a greater measured length than actually exists.

Representativeness: In Phase 3R assessments, the reference reach is a segment of a stable river or stream that is of a similar stream and valley type as the project reach. Data collected within the reference reach are used to help assess the study area for purposes of river assessment, restoration, stabilization, or enhancement. It is important to select a reference reach that will reflect and be as representative of the project reach as possible and in a location in which any upstream watershed disturbances, and any effects from characteristics in the project reach if on the same river, have been minimized. Any data from an active stream gage station should be as close to stream type to the reference and project reaches as possible, although not necessarily within the same watershed or river system, but representative of a similar environment. (See discussion under Section A6, Task 2).

In Phase 3R assessments, cross-sections will be taken at locations which are no more than 5 bankfull widths apart. There will be a minimum of one cross section for each river characteristic (*i.e.*, riffle, run, pool, glide, step) that is present in the reference reach, and a minimum of one for each feature that is present and identifiable in the project reach. For Phase 2 assessments, cross-section locations are determined after first walking the entire reach or segment. Then, cross-sections are set for survey in locations that are representative of the reach or segment as a whole, based on the walk-through and that is on a straight section away from the influence of meander bends, and that is preferably on a riffle. In Phase 3S assessments, cross-sections will be collected at interval spacings no greater than 1.5 bankfull widths apart, unless a detailed point topographic survey is conducted.

Pebble count representativeness depends largely on randomized sampling, and depends on the field staff person picking up and measuring the pebble directly under the front of their boot, and performing this action without bias.

The procedures presented in this QAPP are well established procedures; the measurements taken of the study and reference reaches in Phase 3 assessments will adequately represent the morphology of the river banks.

Comparability: The QAPP will standardize the protocol for data measurement and collection, and ensure data collection is repeatable and comparable over time, personnel changes, or against data from similar projects. These data must be collected with the same tolerances and methods for each survey and sampling within the project. When collection techniques remain consistent, these data become more valuable for use in comparison to future and past measurements.

Completeness: Results from bankfull calibration and reference reach surveys will be provided to the NHDES Watershed Management Bureau and Geological Survey for possible inclusion in

Regional Hydraulic Geometry and reference reach databases. The project manager will determine whether the field data and samples collected are sufficient to accurately characterize the river and stream reaches assessed.

Quantitation Limits: There are no action limits or detection limits associated with this project, therefore there are no quantitation limits.

A8 – Special Training/Certification

Data collection is conducted and/or overseen by a qualified hydrologist, engineer, geo-morphologist, or geologist. The project manager will be trained in and have a minimum of 5 years of stream morphology data collection, analysis, interpretation, and stream survey techniques experience.

The project manager is also responsible for assuring the field assistants are trained to perform fieldwork. The project manager will conduct the training, and/or supplement and fine-tune any prior training the field assistant has had. This training incorporates operation and appropriate use of field instruments and equipment, procedures for taking accurate, comprehensive and readable field survey notes, analyzing field data, and understanding the appropriate need for accuracy and quality control in data collection. Field assistants are required to be familiar with the QAPP and SSPP. Field assistants must demonstrate proficiency in calibrating and operating the field equipment and instruments. The training also includes basic fluvial geomorphology theory, river classification, and assessments techniques.

The use of Table 5 is optional. If applicable, it serves to document specialized training, recurrent training, or certification that has been completed by personnel. It can also list typical tasks on which personnel would need to be trained.

Table 5. Special Personnel Training

Project function	Description of Training	Training Provided by	Training Provided to	Date Completed

A9 – Documentation and Records

All documents will be stored electronically on the project manager’s computer system, in project-specific folders. Files are to be backed up daily. Project files are archived and kept indefinitely. Hard copies of field data, field notes, second hand data, or print outs of on-going work will be stored in a file located on the premises. A copy of the approved QAPP and all associated SSPs will be electronically stored in NHDES’s database and a hard copy will be retained in the project file. Major changes to the QAPP will be submitted to EPA and NHDES for approval.

The project manager and field assistants will maintain all field notes. Copies will be kept with the file folder. Team members will retain the original copies. Field notes must be completed on-site at the time the data collection occurs. Standard symbols and labels for recording stream surveys are used as per Appendix A – Ch.5, Pg. 14. All electronic field documentation, such as GPS points, and electronic notes, will be stored in a manner similar to project hard copies. The minimum required information to be included is as follows:

- Project Name
- Company
- Project Manager
- Survey Team members
- Date
- Detailed location of measurement
- Type of data collection (profile, cross-section, pebble count, Phase 2 geomorphic assessment, etc.)
- Time of Day
- Weather conditions
- Any necessary notes or supplemental forms used
- Equipment used – to include manufacturer type and serial number
- Legend
- Town
- Reach or segment ID number (if on a river for which a Phase 1 or Phase 2 assessment has been conducted – check with NHDES Fluvial Geomorphology staff if unsure)

Photographs will be collected using a digital camera, which will be GPS-enabled and capable of collecting and storing the latitude/longitude point at which a photograph is collected. Photo documentation will clearly display the entire bankfull channel of the cross-section being surveyed, to include:

- Both banks;
- The tape in place across stream;
- A chalkboard (optional - Phase 3 assessment only) with following information: location, date, vantage point; and
- Project benchmark used (displayed in another photo).
- Also include photos of the upstream view, downstream view, right bank view and left bank view from the cross-section.

Most modern digital cameras incorporate features that allow for documentation to be recorded within the photographs. For Phase 3 assessments, this feature can be used as a substitute for a chalkboard. For all assessments, if a GPS point is not able to be recorded, the feature noted shall be documented and location noted in a paper photolog if a chalkboard is not available. If the digital camera possesses the capability to record the compass directionality of collected photographs, this information will also be recorded.

Changes will not be erased, but crossed out and the updated information will be written next to the original value.

Upon completion of a stream morphology data collection project, the Project Manager will submit to NHDES copies of all GIS and GPS files produced by a specific Phase 2 or Phase 3 assessment. As collected, these files should include the locations of the following indexed features: alluvial fans, river corridor encroachments, grade controls, bank erosion, mass failures, bank revetments, log jams, water withdrawals, stormwater inputs, beaver dams, flood chutes, headcuts, stream fords, channel alterations, cross-section locations and locations of wood logs. The Project Manager will also submit to NHDES the photographs and, if applicable, photograph directionality information, and photocopies of all field data collection sheets, which may be submitted as digital scans.

B1 – Sampling Process Design

The phase of project process design needs careful consideration and planning. Thorough planning provides a greater chance for success. Before going out in the field and conducting river surveys, it is imperative to do ample research on the area in question. In most cases, benchmarks, gages or reference sites are already in existence. When conducting reference reach surveys in a Phase 3R assessment, sites will preferably be located in the project watershed upstream of the project reach. Otherwise, a nearby watershed with similar stream and valley type will serve to represent the study area. If neither one of these situations is feasible for the project reach of interest, such as where eligible places for reference reaches are in positions in watersheds that have been modified, Phase 3S, is an option. Several questions need to be answered, and the answers will make selection of a suitable reference reach and subsequent survey sites easier. In planning for a Phase 2 assessment, these questions can also guide the selection of specific reaches to assess.

- Do we have permission from landowners?
- What do we want to know about this stream or drainage?
- What variations (geology, elevation, land use) exist in the area?
- How can we set up the most useful comparisons with the fewest sites?
- How can this site contribute to existing or planned efforts?
- What reaches or segments have features that have specific environmental quality or public safety issues that would benefit from the data collected in a river assessment?
- How much can be accomplished with existing resources?

A day spent researching files, and contacting individuals that have an interest in the channel (such as local angling and fishery agencies, river advisory committees, local town officials, conservation commissions, watershed organizations, white water boating enthusiasts, abutting landowners, local irrigation district, USGS, USDA etc.) can provide valuable information and existing studies can often be expanded for project specific purposes.

Planning helps to avoid conflicts with other scheduled maintenance work. Planning to study a river or stream reach in July, only to discover that the water flow will be diverted for a few weeks while a culvert reconstruction is underway, would be a potentially costly mistake. Field work needs to be coordinated with other scheduled projects, if there is any chance of interference. Mistakes such as these could throw off the project timeline and potentially cause a missed deadline. Studying regional climate, geology, land type, vegetation, historic land uses, and forest plan guidelines can provide a valuable overview of a watershed's character. Planning must be done well in advance of the actual surveying. Access to the sites should be considered, if access needs to be requested. Work should be done during low flow periods; times of peak runoff should be avoided.

Phase 2 Assessments – Once Phase 1 data compilation (stream and meander centerlines, reach breaks, valley walls) has been completed and property access issues addressed, Phase 2 field assessments of river or stream reaches so selected may begin. Data will be collected on valley and river corridor features, stream channel form via cross-sections, condition of riparian banks, buffers and corridors and channel bed and planform changes.

Reference Reach (Phase 3R Assessments) - Once the inventory has been completed on the project reach and surrounding watershed, planning the reference reach and survey sites can begin. A nearby stable segment of a river or stream with similar stream and valley type, slope and channel material, will be selected spanning at least one complete meander wavelength of no less than 20 channel widths distance along which the profile will be surveyed, based on criteria described in Section A6, Task 4. Cross-sections representing one of each feature that is present in the reach (riffle, run, pool, glide, step) should be identified and marked for survey.

Project Reach (Phase 3 Assessments) - Within the project reach, at least one cross-section for each feature present and identifiable, should be marked for survey. Criteria for site selection can be found in Appendix A – pp. 6-7. Once ready to begin field surveys, a benchmark or initial reference point should be identified. Occasionally a previously established benchmark can be found near the project site (the U.S. Geological Survey uses brass monuments set in a rock, a concrete pylon, or a pipe driven deeply into the ground). If one is available, use it. Usually, though, a new benchmark will need to be established at an arbitrary elevation. If possible, hardware such as a base station GPS can be set up in order to establish an elevation tied to an actual datum, particularly so that data can be compared with project design plans at a future date.

Stream morphology surveys will involve measurements of the following areas:

- Dimension – Cross-Sections (Phase 2 and Phase 3 assessments);
- Pattern – Plan View (Phase 2 and Phase 3 assessments);
- Profile – Longitudinal profile (Phase 3 assessments); and
- Channel materials – Pebble Count (Phase 2 and Phase 3 assessments) and Bar/Bulk sample (Phase 3 assessments).

Discussion on data collection methods follow.

B2 – Sampling Methods

Consistency in data collection is vital. Basic procedures conducted for stream data collection are intended to be consistent from year to year, to yield precise, accurate, and comparable assessments of the project reach.

<u>Task 1 – Collection of Available Data</u>

1. Obtain historical and recent aerial photography - photographs can be obtained from a variety of sources. The National Aerial Photography Program (NAPP) in coordination with the USGS and the Aerial Photography Field Office (APFO) associated with the USDA both have national coverage. NAPP produces full national coverage every 5-7 years. Each photo is centered on a quarter section of a standard USGS topo map, and is orthorectified. The photos come in black and white or color IR, which aids in identifying vegetation differences. They are also available in digital format (DOQ – Digital OrthoQuad) at 1:24,000 scale and follow the National Map Accuracy Standards for distance and direction measurements. Historical photos are dated back to 1940.

   APFO has monochromatic photography rectified to scale, which results in a photographic map, accurately representing ground features. Annual photos are taken during the summer months, these photographs are at a 1:7,920 (1" = 660') scale but not geo-referenced. Photographs are available in scales ranging from 1:6,000 to 1:80,000 and are dated back to 1935.

   Photographs can be obtained from the following places:

   - Directly through the USGS (both current and historical) at the following web site: http://earthexplorer.usgs.gov.
   - Directly from the USDA through their web site www.apfo.usda.gov.
   - NH DOQ's can be obtained from NH GRANIT, New Hampshire's statewide GIS clearinghouse at http://www.granit.unh.edu. NH GRANIT has photographs available for individual download, and also has GIS servers which can directly feed the photographic coverages for recent years directly into an ArcGIS project. Historical aerial photography is also available for select years and locations in the state.
   - Aerial photos can also be found at local cooperative extension and USDA offices. These photos are often not rectified so scale must be calculated before any measurements can be taken. Photos that are not orthorectified typically have considerable warp that needs to be accounted for. Thus, orthorectification will need to be performed for any photograph for which this has not been completed.

The New Hampshire Geological Survey has been acquiring old photographs and has performed orthorectification in select locations. Survey staff can provide information on availability and status.

2. When performing a Phase 1 assessment (in preparation for a Phase 2 assessment), it will be necessary to digitize stream centerlines at the 1:5000 scale, from which meander centerlines are derived. Digitization to this scale has already been completed for some rivers and streams

in New Hampshire, and further work to refine the scale of centerlines is underway. Contact staff in the New Hampshire Geological Survey at NHDES for availability and status.

The Soil Survey geographic (SSURGO) database for New Hampshire may be obtained from NH GRANIT at http://www.granit.unh.edu.

3. Understanding the surficial geology of a river system (both the channel and its valley) is important for all assessments as the surrounding surface materials can influence the morphology of a river. This information is available for much of southern New Hampshire and select locations in the White Mountains. Contact staff in the New Hampshire Geological Survey at NHDES for availability and status in the locations for which assessments will take place.

4. FEMA Flood Insurance Studies and maps are available at https://msc.fema.gov or call the FEMA Map Assistance Center, Tel. 877-336-2627 to request annual reports on flood profiles, flood elevations, flood histories, and flood risk zones. Hydraulic model input data are generally available in hard copy directly from FEMA.

5. Information on wetlands is available through the National Wetlands Inventory, the shapefile for which may be downloaded from NH GRANIT (http://www.granit.unh.edu/).

6. For Phase 3 assessments, regional hydraulic geometry curves are available by contacting NHDES.

7. Obtain active and inactive stream flow measurement data (USGS 9-207 forms – "summary of discharge measurements") through NSIP – National Stream flow Information Program at http://water.usgs.gov/nsip. The USGS also publishes annual Streamgage Data and Flood reports, listing daily stream flow values at each gage. This is well archived, well documented, and unbiased water data.

8. As an alternative or supplement to the USGS stream gage data, particularly for ungaged rivers and streams, StreamStats is available for New Hampshire. StreamStats is a web-based tool that includes regression equations that can be used to identify approximate flood discharges for recurrence intervals ranging from 2- to 500- years. The tool is available at http://water.usgs.gov/osw/streamstats/new_hampshire.html. It is important to note that StreamStats allows you to calculate peak flow estimates very easily, and thus, it could very easily be used without understanding some limitations that underlie the analysis, which is important to know. So, be careful! More information can be found at the above web page.

9. Create general location map of the study area on a USGS topo map and a field sketch map as per Appendix A – Ch.3, Pgs. 8-12.

Task 2 – Phase 2 Assessments

A detailed description of the Phase 2 geomorphic assessment is provided in the Vermont Stream Geomorphic Assessment Protocols, Phase 2, 2007 version. The protocols are divided into seven steps, which are assessed per reach, defined through the Phase 1 assessment. Certain river features (such as bars, mass failures, lengths of eroding streambank, etc.) are tallied in a reach assessment. Tallies are typically performed during the initial walk through a reach. During this walk-through, field staff also identify the best locations to site cross-sections at sites that are most representative of the reach. Parameters that encompass the overall reach condition (Steps 1, 3, 6 and 7) are completed after the reach has been surveyed and the cross-sections have been collected.

A digital photographic log of the river or stream will be collected along with GPS points of their locations. If a photo is taken at a location where a GPS point cannot be collected, the photographed feature will be documented in writing and the location noted. At cross-sections, photographs will be taken that include an upstream view, downstream view, right bank view, and left bank view, while ensuring that the cross-section with measuring tape stretched across the channel is incorporated into at least two photographs. Photographs will be collected at all river or stream features identified as components of the Feature Indexing Tool (FIT) within the Vermont Stream Geomorphic Assessment Protocols.

GPS points will be taken for all feature locations that are components of the FIT and locations of cross-sections. A minimum of two (2) cross-sections will be collected, unless channel morphology does not provide sufficient locations to complete this on a relatively straight reach of stream. A third cross-section in a reach may be assessed if the addition of such cross-section will allow refinement of the ability to type the stream within the reach. In the event that the river reach is too deep for wading, and the reach is not within an impoundment, cross-section data may be collected by boat or canoe. The boat or canoe will be tied to a tagline that is fixed across the channel at the cross-section. Measuring rod readings will then be collected along the cross-section from the boat or canoe affixed to the established tagline. Bankfull depths will be measured at additional locations on the established cross-section where morphological change occurs that would otherwise not be captured using 10 measurements. These locations include when the character of the bed material changes from one dominant size class to another, based upon experienced field observation, and where a change in bed elevation is not gradual, such as a sharp drop or rise in bed elevation on the cross-section. In cases where a cross-section traverses a major feature, such as a bar, or exposed bed, measurements shall also be taken of the start, middle, and end of such feature. Cross-sections are measured left to right looking downstream.

If the reach or segment is too deep for wading, a grab sampler can be used to estimate the bed particle size. The sampler will be operated from a boat or canoe in straight reaches of the channel away from the influence of meander bends and the dominant particle size will be estimated based upon visual assessment of the collected sample.

The locations of valley walls will be verified using GPS at all locations for which cross-sections are collected in each reach. Visual evaluations of the match between the locations of the valley wall in the field compared to that derived in the Phase 1 assessment will be made. Locations of valley walls will be verified using one of two methods, as follows:

1. GPS points may be collected at the location of the valley wall in the field; or

2. The distance and compass bearing will be measured from the streambank where a GPS point is collected to the valley wall and record this measurement in a manner that clearly identifies the association of the measurement with the point collected.

Verifications will be attempted when the actual valley wall and Phase 1 mapped valley wall are not reasonably congruent.

Task 3 – Stream Gage Survey (Phase 3 assessment)

As the stream gage survey begins, refer to Appendix A – Ch. 5, for a quick refresher on surveying basics. When taking field notes, use standardized symbols and labels for recording measurements. **Cross-sections are surveyed left to right looking downstream**.

Cross-sections near the stream gage should be situated in a location that has clear bankfull indicators, has a channel form not controlled by a structure, and for which the drainage area at the cross-section location does not differ by more than 10 percent from the drainage area at the gage.

For a step by step procedure for calibrating bankfull discharge see Appendix B. For a more in depth discussion of bankfull and floodplain indicators see Appendix A – Ch. 7, Pgs. 33-36.

Task 4 – Reference Reach Survey (Phase 3R assessment)

Where employed, reference reach surveys are used to develop restoration design criteria based upon measured morphological relations associated with the bankfull stage for a specific stable stream type (Rosgen, 1996). It is important to do ample research and choose the reference reach carefully, since the purpose of the computations derived from survey measurements is to extrapolate data to disturbed river segments. Aerial photos can aid in identifying stable segments along the channel by depicting time-trends in river morphology pre- and post-flooding.

A detailed discussion on the protocol for reference reach surveys is found in Appendix C.

- To complete cross-sectional surveys, the channel must be waded repeatedly. For safety purposes the work must be performed during low flow.

  Natural ground, channel bed, and water surface elevations should be collected along each cross-section feature to include a riffle, run, pool, and glide, for each that is present in a reach. (See Appendix A - Ch.6 for survey methods.)

  Photo documentation must be included for each cross-section. Photographs will include an upstream view, downstream view, right bank view and left bank view, while ensuring that the cross-section with measuring tape stretched across the channel is incorporated into at least two photographs. A benchmark needs to be set up, as per Appendix A – Ch 5, Pg. 15.

  Distances are measured to 0.1 ft. Elevation measurement locations should be spaced a minimum of 1/20th of the bankfull width apart with closer spacing along the banks, at possible bankfull indicators, at major breaks in slope, or other areas where needed, such as when the character of the bed material changes from one dominant size class to another, based upon experienced field observation, or if the cross-section traverses a feature such as a bar. Often elevations of the channel bed and adjacent land are measured to tenths (0.1) of a foot for cross-section and profile surveys, especially when moving the rod a few inches horizontally affects the elevation reading dramatically. However, taken to hundredths will increase the accuracy to a desired standard. Precision is always taken to hundredths (0.01) of a foot for benchmark, turning points, height of instrument, water surface, and bankfull indicator measurements.

Cross sectional surveys at riffles should extend beyond the bankfull channel to include the flood prone area, in order to measure its width and calculate the entrenchment ratio. Further discussion and protocols for cross-sectional river surveys can be found in Appendix A – Ch. 6.

- Longitudinal Profile Measurement procedures are discussed in Appendix A – Ch. 8. The following should be collected:

  Thalweg, water surface, bankfull, and top of bank along the profile (minimum 20 bankfull widths or 2 meander wavelengths in length). Also note the cross-section locations along the profile. (See Section B2 and Appendix A – Ch.8 for methods).

  Whether the longitudinal survey is done before or after the cross-sectional surveys is a decision made based on experience and what works best for the particular channel characteristics. In some instances, having the elevations of the water surface, riverbed, floodplain, bankfull stage, and terraces may help in deciding where to locate cross-sections.

  Further discussion on longitudinal profiles is presented in Appendix F. Also included in Appendix F is an example of a profile with measured features identified.

- Channel bed composition is needed to classify and characterize the stream. A discussion on bed and bank material characterization can be found in Appendix A – Ch.11.

  The pebble count is done following the survey. At that time the channel features (*i.e.*, riffles, runs, pools, glides, steps) will have been quantified. During the pebble count no less than 100 samples are needed to obtain a valid count. The amount of sampling within each of the features is relative to the percentage of the whole study reach that the feature comprises. For example, if it is determined that the study reach is made up of 30 % pools, 40 % riffles, 10 % runs, and 20 % glides, then 30 samples in three separate transects in pools, 40 samples through 4 transects across riffles, 10 samples across one transect across a run, and 20 samples from 2 transects across glides should be taken. The sampling is along the whole bankfull width, regardless of water surface elevation, so that all area between the bankfull elevations is representatively sampled.

  The procedure to be followed is the Wolman Pebble Count (1954) which is discussed in Appendix A – Ch.11. Pebble count data forms can be found in Appendix D.

- Plan View measurements of the Reference Reach should include:
  - Stream length
  - Valley length
  - Meander length (L_M)
  - Meander radius (R_C)
  - Belt Width (W_{BELT})

- Arc Length (L_{ARC})

Guidelines for making plan view measurements can be found in Appendix E. If dense vegetation or river size precludes field measurement, these can be made using recent aerial photographs which have a calculated scale as long as no major changes in channel alignment have occurred between the photo date and the date field work is performed.

Task 5 – Project Reach Survey (Phase 3 assessments)

Phase 3R assessment
The procedures to conduct the project reach survey will be the same as those used for the reference reach. Depending on channel condition, distinguishable channel features may not be present, but those that can be identified should be used. If possible, a reference mark shown on a FEMA Flood Insurance Rate Map, or a national geodetic survey marker or elevation mark on transportation infrastructure such as a road or bridge, should be used as a survey benchmark.

- Discussion and protocols for cross-sectional river surveys can be found in Appendix A – Ch. 6.
- Longitudinal Profile Measurement procedures are discussed in Appendix A – Ch. 8 and Appendix F. Included in Appendix F is an example of a profile with measured features identified.
- Bed and bank material characterization can be found in Appendix A – Ch. 11. The Wolman Pebble Count (1954) procedure should be used (see Appendix D).
- Guidelines for making plan view measurements can be found in Appendix E. If dense vegetation or river size precludes field measurement, these can be made using recent aerial photographs which have a calculated scale as long as no major changes in channel alignment have occurred between the photo date and the date field work is performed.
- All surficial geologic controls and valley characteristics in the project reach will also be noted and recorded.

Phase 3S assessment
Phase 3S assessments have similarities to the Phase 3R assessments, with the following modifications to enable a larger dataset capable of supporting a more analytical approach to restoration projects:

- Survey cross-sections, to be spaced at distances no greater than 1.5 channel widths apart, using the methods stipulated in the Phase 3R assessments for cross-section survey.
- Topographic survey of the reach with a total station that uses either a local or GPS-based (preferred) coordinate system (using a GPS-RTK unit), capable of survey accuracy to 0.02 feet, where a detailed survey of points in the reach captures as many different landscape features as possible. Point densities will vary spatially with higher point densities in topographically complex areas (considerable variations in ground surface with short distances), and lower densities in areas of more level terrain. In areas with greater variation, densities should be near 2 to 3 points for every 10 ft^2 of ground surface area, with 1 point every 10-20 ft^2 in areas with more level terrain. In these surveys, the

equipment used will possess the capability to note and store specific features (*i.e.*, bankfull indicator, bars).

- GPS points of the start and end of a Wolman pebble count, plus each location where the count reaches a bankfull indicator while in progress will be collected.
- The spatial extent of the data collected will be sufficient to capture the influence of all features that are believed to affect the project reach.

Task 6 – Sediment Transport Evaluation (Phase 3 assessments)

- The riffle pebble count is performed using the sampling methods described for the Wolman Pebble Count procedure with the exception that samples are collected only from the bed of riffles (no bank material samples are taken). A minimum of 100 samples are required.

Protocol for Bar/Bulk Sampling can be found in Appendix F along with a corresponding form for recording data. The minimum depth of material to be excavated should be 4-6 inches when the largest particles are measured to be < 2 inches at their intermediate axis. Otherwise the depth to be excavated should be twice the diameter of the intermediate axis of the largest surface particle. Wet-sieve the excavated materials in stages. Occasionally weigh, record, and then dispose of the materials in the sieves, saving the fine-grained sediment remaining in the bottom of the bucket. Fine-grained material (< 2 mm) remaining in the bucket is weighed after all coarse-grained material in the sample has been sieved and weighed.

B3 – Sample Handling and Custody

All samples collected during the pebble count and bar/bulk sampling will be measured and weighed, tallied and classified in the field at the time of collection. The date and time of collection will be recorded in the field book. The field team conducting a pebble count will consist of a minimum of two people. One field team member will pick samples, measure them, and call out the measurements, while the other tallies the samples, writes down the measurements according to size and repeats them back for confirmation. It is the responsibility of each team member to make sure the measurements have been properly communicated. Once the sample data have been confirmed and tallied, the sample can be disposed of behind the direction of traverse.

For bar and bulk sampling, once the location of the sampling has been determined and the bottomless bucket has been put in place, material to a depth of twice the diameter of the largest surface particle, or 4-6 inches if the largest particles are less than 2 inches at their intermediate axis, is excavated and placed into a container for transport to a level area. Here the sieve set is assembled and wet-sieving the collected sample will be conducted. This process is performed in stages. As the sieves fill up, they are taken apart and weighed individually. After the measurements have been confirmed, the materials are disposed of and returned to the stream bed. If there is any question to the validity of this data, the sampling will be repeated.

B4 – Analytical Methods

Analysis protocols and explanations are detailed in each corresponding Task Appendix as described in Section B2 – Sampling Methods.

For Phase 2 assessments, the collected cross-sections and pebble count data may be entered into and plotted in a Phase 2 survey datasheet, which is available from the New Hampshire Geological Survey at NHDES.

For Phase 3R assessments, bankfull calibration forms are contained in Appendix B. Semi-logarithmic graph paper for plotting particle size distribution of pebble count, riffle pebble count, and bar/bulk samples is included in Appendix D. A Plan view schematic drawing showing plan view measurements and calculations is contained in Appendix E. Cross Section and Longitudinal Profile plots and calculations are included in Appendix F. Cross-Sections and profiles can be plotted on standard graph paper or using one of several computer programs. They should be plotted to scale. Appendix H contains Reference Reach Stream Channel Classification, Reference Reach Summary Data, and reference reach field forms that can be used during the analysis phase. There is no specialized equipment needed for analysis.

For Phase 3S assessments, the more detailed topographic data collected can be utilized for the creation of topographic contour surfaces and for use in creating 1- and 2- dimensional flow models (including but not limited to HEC-RAS, Flo-2D, FESWMS, etc.) for the project reach. Such models can be used to characterize sediment transport and shear stress thresholds in order to aid design of properly sized stream restoration treatments. Topographic data collected with a total station is imported into ArcGIS or CAD. Within ArcGIS, tools are available to extract cross-sections from topographic contour surfaces as needed. Where HEC-RAS or CAD is used for data processing and modeling, all parameters of infrastructure within the reach (culverts, berms, bridges, roads) will be input to the model.

The following analyses are performed after all the data have been collected and plotted. The resulting values are used to determine stream type, assess channel stability, develop restoration plans, and predict channel response to physical alteration or land use change. Detailed discussions on stream assessment and restoration design are beyond the scope of this document, however, they are founded on the data collection techniques and analysis discussed herein.

CHANNEL DIMENSION - Cross-Sections (Phase 2 and 3 assessments)

- Bankfull Width (W_{bkf})
- Bankfull XS Area (A_{bkf})
- Mean Bankfull Depth ($D_{bkf} = A_{bkf} / W_{bkf}$)
- Maximum Bankfull Depth (D_{maxbkf})
- Width of Flood Prone Area (W_{fpa} = Width at 2(D_{maxbkf}) measured from the thalweg)
- Width-to-Depth Ratio* ($W/D = W_{bkf} / D_{bkf}$)
- Entrenchment Ratio* ($= W_{fpa} / W_{bkf}$)

CHANNEL PATTERN - Plan View (Phase 3R assessments)

- Sinuosity* (K = stream length / valley length or valley slope / stream slope)
- Meander Length (L_m)

- Meander Radius (R_c)
- Belt Width (W_{belt})
- Meander-Width Ration (MWR = W_{belt} / W_{bkf})

<u>CHANNEL PROFILE – Longitudinal Profile (Phase 3 assessments)</u>

- Average Channel Slope* (S = elevation drop / stream length)
- Elevation drop is typically measured as the change in water surface elevation between the upstream and downstream end of the profile over a minimum distance of 20 bankfull widths
- Valley Slope (elevation drop / valley length)
- Slope and length of channel features (*i.e.* riffle length, riffle slope, pool length, pool slope, etc)
- Pool-to-Pool Spacing

<u>CHANNEL MATERIALS (Phases 2 and 3 assessments)</u>

- Particle size distribution from pebble count
  - **D_{50}*** = median size of channel bed material
  - Minimum 100 samples taken from bank to bank
  - Measure intermediate or “B” axis of stone (*i.e.* not the longest or shortest dimension)

*** denotes variable required for stream classification**

Note: In Phase 3S assessments, a topographic contour surface created from the collected data can be used to extract cross-sections and channel longitudinal profiles from. Features, such as bankfull indicators, will be available from notation during the topographic survey.

B5 – Quality Control

In stream morphology data collection there are no contamination issues. There are no time limits to handling, storing, and transporting samples. Systematic introduction of bias is minimal. The opportunity to introduce error, however, does exist during each measurement activity. Quality control is not quantifiable in most cases, and it becomes a subjective assessment of whether data collected appears reliable and qualifies as a valid representation of what is being measured. There are a few steps that need to be taken to minimize imprecision and to identify any errors that might be present. The degree of accuracy that is necessary depends on the intended use of the data.

In the initial collection of available data and research phase, it is important to be as thorough as possible and to get historical data and photography. When calculating scale on photographs, the more measurements used to calculate average scale, the more precise plan view calculations will be. Plan view measurements taken from a series of successive aerial photos spread over several years or decades of the stream reach under study are highly valuable in quantifying changes in channel pattern and the land uses or channel alterations which may have caused them. Major changes in channel pattern can often be linked to specific flood events if stream gaging data or local flood history is known. Quality control for collection of second hand data is discussed in Section B9 – Data Acquisition Requirements.

For Phase 3 assessments, stream gage and bankfull calibration survey data are invaluable for accurately characterizing the stream reach and reference reach being studied. Slope, channel materials, width-to-depth ratio, entrenchment ratio, and sinuosity of the study reach are needed to determine the existing stream type in both Phase 2 and Phase 3R assessments. When a reference reach is used, it should, as accurately as possible, represent a section of river or stream channel that has minimal disturbance. If the condition of the stream channel under study is disturbed, the selection of a suitable and representative reference reach can be challenging and one may need to survey a stream reach in an adjacent or nearby watershed, or wholly use a site-specific assessment method (Phase 3S) in the project reach. The valley types and slopes of the two reaches should be similar**. A maximum variation of +/- 30% is recommended (*i.e.*, 1.3 > (study reach slope / reference reach slope) > 0.7).** In addition the channel materials in the two reaches should be similar (*i.e.*, if the study reach is a gravel bed stream the reference reach must also be a gravel bed stream).

All project reach cross-section surveys in Phase 3 assessments begin and end at benchmarks of known elevation. All surveys will be closed in the field, and no survey will be complete until it has been closed within the acceptable levels of error of 0.01 ft. If a survey does not close within this tolerance, then it is conducted again. Before a survey is started, confirm that the tripod base is level and the bubble is centered. This should be rechecked periodically. Make sure the rod is plumb when making measurements. The rod should be moved through the axes, until a minimum reading is determined. Ensure that the elevations are read to the central cross hair. Misreading elevation is a common cause for error.

In Phase 2 assessments, cross-section surveys are not tied to an elevation benchmark, but rather are set based on the bankfull indicators of the location in which the cross-section survey is conducted. Given that bankfull indicator identification in the field can pose challenges, all members of a field team should discuss, and be in agreement on, the location of bankfull indicators by which to base the cross-section siting. Ensuring that the measuring tape for the cross-section is taut across the channel, and is situated perpendicular to the main flow lines is critical. One member of the field team should examine the tape to ensure that both of these factors are correct before survey begins.

For all pebble counts conducted, the 100 random samples that are collected typically give an accurate representation of channel bed materials. Samples are distributed over several transects through several channel features. If the channel is very wide, if the size distribution varies excessively throughout transects of similar channel features, or if the team members feel that the samples collected are insufficient to make an accurate assessment, then more samples will be collected. For quality control, the sampling process roles can be alternated.

After the data points are plotted, any inconsistencies should be addressed. All team members should review the analysis calculations for errors. Any discrepancies need to be researched and if the error is not determined, the necessary data need to be measured again.

B6 – Instrument/Equipment Testing, Inspection, Maintenance

Records will be maintained for all instruments used to ensure conformance to specified requirements. The instrument is evaluated before use to confirm it can be calibrated to the degree of accuracy necessary to accomplish the task for which it has been assigned.

The following instruments are calibrated by the team members or qualified technicians to allow for the maintenance of accuracy in the required measurement capability. Compliance with calibration schedules will be confirmed before each job is begun. The instruments are calibrated using methods and frequency per manual specifications, or when dropped, mishandled, kicked, submerged or similar. A discussion on the care of survey instruments can be found in Appendix A – Pg. 19.

- Surveyor's Level and tripod (with or without stadia)
  A survey instrument should be checked for accuracy the first time it is used. This can be done by performing the 2-peg test, which is explained in Appendix A – Pg.20. If the elevation differences are greater than specified in the test, the instrument needs to be adjusted by a qualified technician.
- Laser Level
  A laser level should be checked before field work is begun, the first time it is used, when damage is suspected, or when custody of the instrument changes. Most laser levels can be easily calibrated per instructions contained in the user's manual. If accurate calibration cannot be achieved, the instrument must be serviced by a qualified technician.
- Transit (qualified technician)
- Total Station (qualified technician)

The following instruments need to be checked for integrity and accuracy, but calibration can be performed in-house.

- Leveling rod (English or metric standard)
  The rod should be checked for bowing, damage to ends, restrictions to full extension, and numbering visibility. It should be calibrated to an object of known length.
- Survey tapes (to match rod, minimum gradations to 0.1 ft. or 0.01 m)
  A fiberglass or steel tape is preferred. It should be checked for missing sections/ends, kinks, and any damage to the coating which would compromise accurate measurements. At this time it would need to be replaced. Nylon coated steel cam-lines are frequently used to perform cross-sections of large rivers as they are much more wind resistant than fiberglass tapes.
- Household kitchen scale
  Scale will be calibrated with known weight annually, or if damage or mishandling is suspected. Scale will be zeroed, or checked for zero before each measurement is taken.
- Sieve-set (2, 4, 8, 16, 32, 64, 128, and 256 mm size)
  Sieve set will be inspected for excessive wear or broken or misshaped mesh before each use.
- GPS Receivers
  A GPS unit should be checked for accuracy the first time it is used. The GPS unit will be benchmarked with a position of known geographic location at the beginning and at the end of

collection period, and average precision/error can be calculated for points collected. If the error is > 49 feet, then satellite coverage was insufficient at that time.

Following is a continued list of equipment necessary to perform river field work. All should be checked to be in good condition and ensured to be in proper working order.

- Field Book (waterproof cover)
- Ruler (mm)
- Digital camera
- Laser rangefinder
- Chalkboard (for photo documentation)
- Small sledge hammer
- 5/8" diameter steel rebar in 24" minimum lengths for cross sectional endpoints, pins, etc.
- Aluminum nursery tags or plastic rebar caps
- Calculator
- Batteries
- Compass
- Clinometer
- Field instructions
- Maps (USGS and Road). A handheld GPS unit or tablet can be used to display this information electronically.
- Flagging
- Stakes and clamps for fastening ends of tape
- Paint (hi visibility orange)
- Bottomless 5-gallon bucket, intact 5-gallon bucket, and 5-gallon bucket with weephole and cover with hole slightly smaller than exterior sieve diameter.
- Safety rope (100')
- First Aid kit
- Two-way radios
- Brush cutter
- Hip or chest waders w/wading belt

The following table can be used to document compliance with maintenance of accuracy for instruments and equipment being used.

Table 6. Instrument/Equipment Maintenance, Testing, and Inspection

Equipment name	Activity	Frequency of activity	Acceptance criteria	Corrective action	Person responsible
	Maintenance (cleaning)				
	Testing (operation)				
	Inspection				

B7 – Instrument/Equipment Calibration and Frequency

See Section B6 - Instrument/Equipment Testing, Inspection, Maintenance for discussion. The following table can be used to document compliance with time-required calibration for instruments used.

Table 7. Instrument/Equipment Calibration

Equipment name	Procedure	Frequency of calibration	Acceptance criteria	Corrective action	Person responsible

B8 – Inspection/Acceptance Requirements for Supplies and Consumables

Not applicable.

B9 – Non-direct Measurements

Historical and recent aerial photography are used for plan view measurements and to determine changes in channel pattern and alignment over time. There is no minimum or maximum scale requirement. The channel needs to be identifiable and clear to get accurate measurements. If possible obtain photographs that are at a small enough scale to identify channel banks. One photograph which contains at least two meander lengths would be optimal for plan view measurements. Photographs need to be vertical to minimize any distortion from oblique angles.

Active and inactive stream gage data needs to meet the following criteria to be acceptable:

- Minimum 20 years instantaneous annual peak flow data. The data do not need to be consecutive.
- Maximum 30% of drainage area is regulated or affected by diversion.
- For inactive stream gages with 20+ years data the presence of a staff gage needs to be verified. Also there needs to be verification that there has not been a substantial shift in the stage-discharge curve due to changes in the channel cross-section. This should be done by comparing a current cross-section at the discharge measurement site to streamflow data. Changes in cross-sectional area up to 5% are acceptable.
- Annual Water Resources Data (WRD) reports and FEMA flood studies are government documents whose accuracy and completeness are verified before publication.

Stream gage data are used to provide insights into the flow and flood histories of sites, which can aid in explaining historical changes seen in aerial photography comparisons where they occur.

USGS 7.5 minute topographic maps are used for scale measurements and to identify site locations, land-use activities, landscape features, valley confinement, and reach break locations during an initial watershed survey.

For a continued discussion see Section B2, Task 1.

B10 – Data Management

All field data sheets to be used in field activities are included in Appendices A, B, D, G, H and M. Field data sheets will be checked for completeness after each survey and at the end of each day. The field team captain will ensure field records are complete before leaving each site, or river/stream reach. The project manager will review field data sheets before data processing commences. Any omissions or discrepancies will be handled immediately and prior to processing and reporting of data. Original field data sheets will remain in the possession of the entity responsible for field data collection, and a copy will be provided to the Project Manager. Refer to Section A9 for a more in-depth discussion on documentation and record keeping.

Any secondary data will be stored in the project file, in either hardcopy or electronic format.

All data will be entered into a computerized database/spreadsheet/computer aided design base program, designed for project needs. For Phase 2 assessments, all necessary databases and spreadsheets will be provided to the Project Manager by the NHDES Fluvial Geomorphology Specialist. Computations will either be done by hand and computer drawings will be manually created, or values for survey cross-sections will be computer generated by the data values entered (particularly the case for Phase 2 assessment data). All computer generated documents will be inspected for validity, completeness and accuracy by the quality control manager and project manager.

For Phase 2 assessments, all GPS points of FIT features required by the Vermont Stream Geomorphic Assessment Protocols will be imported into a GIS and mapped. As each feature is photographed this shapefile should indicate the location of each photo and have attribute fields indicating the photo name and feature being identified. Photos should be stored by reach, by project. The end product of photos, data sheets, and this shapefile allow mapping of both point and linear features in GIS.

All electronic topographic survey data collected with a total station in Phase 3S assessments, and any derivative products, will be provided to the Project Manager.

All project files and drawings will have a unique file name including the project number and name. Every drawing will have a back up copy.

Paper files will be maintained in a secure filing cabinet.

Inactive electronic files are archived, and once archived they are changed to read-only status.

C1 – Assessments and Response Actions

The project manager will monitor and address all activities of the data collection process. Field assistants review field techniques as needed and have a review performed by the project manager annually. Data collection methods are standardized and the reporting method is consistent. The quality assurance manager will ensure that field team members are performing all data collection as prescribed by the quality assurance project plan and site-specific project plan.

All field activities may be reviewed and project sites may be visited by NHDES and EPA Quality Assurance Officers.

C2 – Reports to Management

The following documentation, as applicable to the project, will be presented at the end of data collection and analysis.

- Site sketch or plan showing limits of study and reference reaches, cross-section locations, profile alignment and other pertinent information.
- A photographic log of the river or stream that was assessed.
- Cross-section plots
- Longitudinal profile plot
- Plan-view analysis
- Particle size distribution plots
- Bar/bulk sample results
- Calculations
- Results of bankfull calibration at stream gage including supporting documentation
- Stream classification summary
- Stream restoration plan
- Digital scans of all field data sheets and forms.
- Database containing collected field data.
- Digital files of all total station collected topographic data, and all derivative products.

According to the scope of services listed in each grant agreement, semi-annual progress reports are submitted to DES on special forms each December 31 and June 30. A final project report is submitted when the project is finished.

D1 – Data Review, Verification and Validation

The project QA Officer will review all data collected as well as subsequent calculations to evaluate whether QC requirements have been met and whether data are usable to obtain the stated objectives of the project based on criteria contained in the QAPP and SSPPs. Subsequent final review and approval will be made by the Project Manager.

D2 – Verification and Validation Procedures

Field data are submitted to the Project Manager and QA Officer. The QA Officer reviews all field data for completeness. The Project Manager makes sure that any questionable data are verified by speaking to the survey team or reviewing the field logbooks, and noting any unusual or anomalous data in the project files.

Any decisions made regarding the usability of data will be ultimately left to the Project Manager, however the Project Manager may consult with the QA Officer, project personnel, NHDES staff, or with personnel from EPA-NE.

When it is found that data do not meet the quality objectives from Section A7, or do not adhere to the quality control measures from Section B5, the Program Manager may determine what corrective action must be taken.

- Incomplete data may lead to the need for re-assessment of the affected reach if it is found that the available data are insufficient to meet project goals.
- When data quality is poor, the project manager will apply one of the following actions.
    1. Systems audit for measurements in question;
    2. Immediate on-site re-assessment of the measurements in question;
    3. Rejection of data with a written explanation; or
    4. Rejection of all data from an entire survey transect or reach with recommendation for relocation of survey site.

D3 – Reconciliation with User Requirements

Data will be generated based on the quality objectives defined in Section A7 and verified according to Section D2. Limitations in the data will be clearly defined for potential end users in all reports produced.

If the project objectives from Section A7 are met, the user requirements have been met. If the project objectives have not been met, corrective action as discussed in Section D2 will be established by the Project Manager, in consultation with NHDES staff.

References

Bunte, K., Abt, S.R. 2001. Sampling surface and subsurface particle-size distributions in wadeable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. Gen. Tech. Rep. RMRS-GTR-74. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 428 p.

Demeurichy, K., Wheaton, J.M., Welsh, S., Consolati, F. 2011. Bridge Creek IMW Topographic and Aerial Photography Surveys: 2010-2011 Deliverables. Report to Eco Logical Research, Inc. Logan, UT: Ecogeomorphology and Topographic Analysis Lab, Watershed Sciences Department, Utah State University.

Harrelson, Cheryl C., Rawlins C.L., and Potyondy, J. 1994. Stream Channel Reference Sites: An Illustrated Guide to Field Technique. General Technical Report RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 67p. http://www.stream.fs.fed.us/publications/PDFs/RM245E.PDF.

Rosgen, David.
1996. Applied River Morphology. Wildland Hydrology , Pagosa Springs, CO.
1998. River Morphology and Applications. Wildland Hydrology , Pagosa Springs, CO.
1998. The Reference Reach: A Blueprint for Channel Design. Wildland Hydrology , Pagosa Springs, CO. http://www.wildlandhydrology.com/assets/The_Reference_Reach_II.pdf
2000. River Assessment and Monitoring. Wildland Hydrology, Inc. Pagosa Springs, CO.

Lilles and, Thomas M., Kiefer, Ralph W., 1994. Remote Sensing and Image Interpretation, Third Edition. CRWaldman Graphic Communications, Inc. , R.R. Donnelley, Crawfordsville.

EPA Guidance for Quality Assurance Project Plans – EPA QA/G-5 , December 2002. Environmental Protection Agency, Office of Water, Washington, DC.

EPA The Volunteer Monitor's Guide to Quality Assurance Project Plans – EPA 841-B-96-003 – September 1996. US Environmental Protection Agency, Office of Water, Washington, DC.

NHDES Generic Quality Assurance Project Plan for NH Biomonitoring Program – Racine, Michael. November 2002. NH Department of Environmental Services, Watershed Section. Concord, NH.

Olson, S.A., 2009. Estimation of flood discharges at selected recurrence intervals for streams in New Hampshire. U.S. Geological Survey Scientific Investigations Report 2008-5206, 57 p.

Vermont Agency of Natural Resources, 2004. Vermont Agency of Natural Resources Stream Geomorphic Assessment Protocols Handbook: Remote Sensing and Field Surveys Techniques for Conducting Watershed and Reach Level Assessments.

Vermont Agency of Natural Resources, 2007. Vermont Stream Geomorphic Assessment Phase 1 Handbook: Watershed Assessment. Waterbury, VT.

Vermont Agency of Natural Resources, 2007. Vermont Stream Geomorphic Assessment Phase 2 Handbook: Rapid Stream Assessment. Waterbury, VT.

Vermont Water Quality Division, 2001. Vermont Regional Hydraulic Geometry Curves, Waterbury, Vt.